1. INTRODUCTION

1.1. Overview

THERM is a state-of-the-art, Microsoft Windows™-based computer program developed at Lawrence Berkeley National Laboratory (LBNL) for use by building component manufacturers, engineers, educators, students, architects, and others interested in heat transfer. Using THERM, you can model two-dimensional heat-transfer effects in building components such as windows, walls, foundations, roofs, and doors; appliances; and other products where thermal bridges are of concern. THERM's heat-transfer analysis allows you to evaluate a product's energy efficiency and local temperature patterns, which may relate directly to problems with condensation, moisture damage, and structural integrity.

THERM's two-dimensional conduction heat-transfer analysis is based on the finite-element method, which can model the complicated geometries of building products. The program's graphic interface allows you to draw cross sections of products or components to be analyzed. To create the cross sections, you can trace imported files in DXF or bitmap format, or input the geometry from known dimensions. Each cross section is represented by a combination of polygons. You define the material properties for each polygon and introduce the environmental conditions to which the component is exposed by defining the boundary conditions surrounding the cross section. Once the model is created, the remaining analysis (mesher and heat transfer) is automatic. You can view results from THERM in several forms, including U-factors, isotherms, heat-flux vectors, and local temperatures.

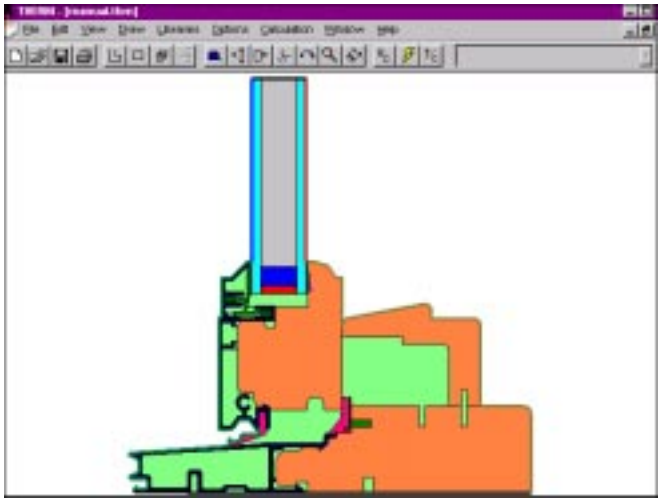

Figure 1-1. Sample THERM window cross section

This version of THERM includes several new technical and user interface features; the most significant is a radiation view-factor algorithm. This feature increases the accuracy of calculations in situations where you are analyzing non-planar surfaces that have different temperatures and exchange energy through radiation heat transfer. This heat-transfer mechanism is important in greenhouse windows, hollow cavities, and some aluminum frames.

THERM is a module of the WINDOW+5 program under development by LBNL. WINDOW+5 is the next generation of the WINDOW software series[1,2] and is being developed for the Microsoft Windows™ operating environment. THERM's results can be used with WINDOW's center-of-glass optical and thermal models to determine total window product U-factors and Solar Heat Gain Coefficients. These values can be used, in

turn, with the RESFEN program, which calculates total annual energy requirements in typical residences throughout the United States.

Update information, future releases, and program information about THERM and the other software tools from the Windows and Daylighting Group at LBNL mentioned above can be found on the World Wide Web at URL: http://windows.lbl.gov. To obtain a copy of THERM, WINDOW, or RESFEN, fax or email your address and phone number to Software Request, Fax: 510 486-4089, email: PLRoss@lbl.gov. If you have questions or problems about using the program, email Thermhelp@lbl.gov.

1.2. New THERM Features

This version of THERM significantly upgrades the calculation and drawing features of the previous program.

1.2.1. New General Features

- 32-bit program compilation allows multitasking and greater detail in models,
- Report of simulation results can be printed,
- THERM files can be exported to a format that WINDOW 4.1 can read,
- Temperature is displayed at cursor,
- Calculation manager can run batch simulations.

1.2.2. New Drawing Features

- Automatic cavity fill feature,
- Drawing can be flipped and rotated to any angle,
- Improved void and overlap detection,
- "Undo" of one level when drawing.

1.2.3. New Calculation Features

- View-factor radiation modeling accounts for self viewing effects. This is particularly useful for modeling projecting products such as greenhouse windows, skylights, and certain aluminum windows (e.g., sliders) that "see" themselves.
- Advanced view-factor radiation modeling for window frame cavities accounts for self-viewing elements in cavities.
- Condensation Index modeling option uses local (as opposed to average) convection correlations in glazing cavities, as well as the advanced view factor radiation model, resulting in more accurate local temperatures than in previous version.
- "Tape measure" calculates average temperatures across any line segment.

1.3. THERM Components

THERM has three basic components:

- a graphic user interface that allows you to draw a cross section of the product or component for which you are performing thermal calculations.
- a heat-transfer analysis component that includes: an automatic mesh generator to create the elements for the finite-element analysis, a finite-element solver, an optional error estimator and adaptive mesh generator, and an optional view-factor radiation model.
- a results displayer.

1.3.1. The THERM Graphic User Interface

THERM has standard graphic capabilities associated with the Microsoft Windows(TM) operating system. For example, THERM allows you to use:

- Both mouse and cursor operations;
- Standard editing features, such as Cut, Copy, Paste, Select All, and Delete;
- A toolbar to access frequently used commands and short-cut keys;
- Multiple windows so several projects can be open concurrently.

THERM has powerful drawing capabilities that make it easy to model the geometry of the cross section of a building component.

You can use two methods to draw a cross section:

- Trace an imported DXF or bitmap file.
- Draw the geometry based on a dimensioned drawing.

The following thermal properties must be defined for the cross section geometry:

- Material properties (broken into two classes: solids and cavities) of each component of the cross section,
- Boundary conditions at the external edges of the cross section.

1.3.2. Heat-Transfer Analysis

THERM uses two-dimensional (2D) conduction and radiation heat-transfer analysis based on the finite-element method, which can model the complicated geometries of fenestration products and other building elements. (A complete discussion of the solution method is available in Finlayson 1995[4] and Curcija et al. 1995[10] as well as in Appendix C of this manual). This method requires that the cross section be divided into a mesh made up of nonoverlapping elements. This process is performed automatically by THERM using the Finite Quadtree method[5]. Once you have defined the cross section's geometry, material properties, and boundary conditions, THERM meshes the cross section, performs the heat-transfer analysis, runs an error estimation, refines the mesh if necessary, and returns the converged solution.[4] See Appendix C for more details.

1.3.3. Results

The results from THERM's finite-element analysis of a fenestration product or building component can be viewed as:

- U-factors,
- isotherms,
- color-flooded isotherms,
- heat-flux vector plots,
- color-flooded lines of constant flux,
- temperatures (local and average, maximum and minimum).

The rest of this manual explains how to get started using THERM:

- how to install the program,
- how to draw the cross-section geometry,
- how to define the thermal properties,
- how to perform the thermal analysis,
- how to view the results,
- how to print a report,
- how to export files to WINDOW.